Spring 2011 Midterm

Introduction To Robotics (16-311)
2/28/2001

Name: Answer Key

Group Number: _____

ANSWER KEY

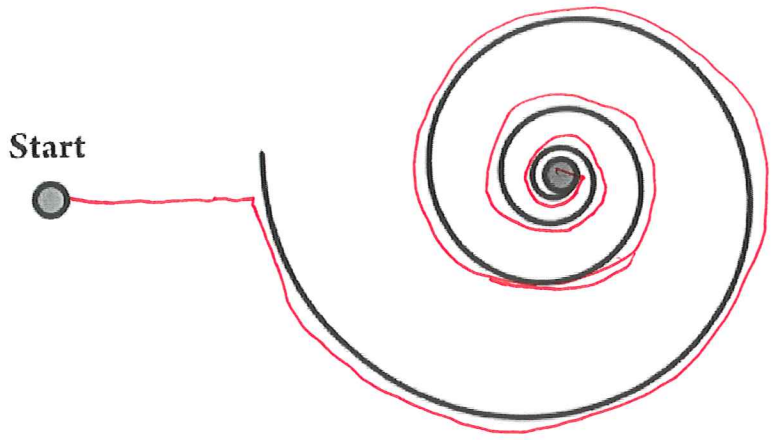
Read all of the following information before starting the exam:

- You have 1hr and 15 minutes to complete this exam.
- When drawing paths, be sure to clearly indicate rounded edges vs sharp edges.
- When in doubt, explain your answer as you might get partial credit.
- Justify your answers algebraically whenever possible to ensure full credit. When you do use your calculator, and explain all relevant mathematics.
- Circle or otherwise indicate your final answers.
- Please keep your written answers brief; be clear and to the point.
- This test has 6 problems and is worth 100 points. It is your responsibility to make sure that you have all of the pages!
- Good luck!

1. (*20 points*)

a. (*12 pts*) Refer to the workspace below. Assume the robot starts in the circle on the left and wants to move the the circle in the spiral. Ignore the radius of the robot (you dont need to pad the obstace). Assume the Bug algorithm rule always turns right. Which Bug algorithm will yield a shorter path for this workspace? Draw that path.

Bug 2



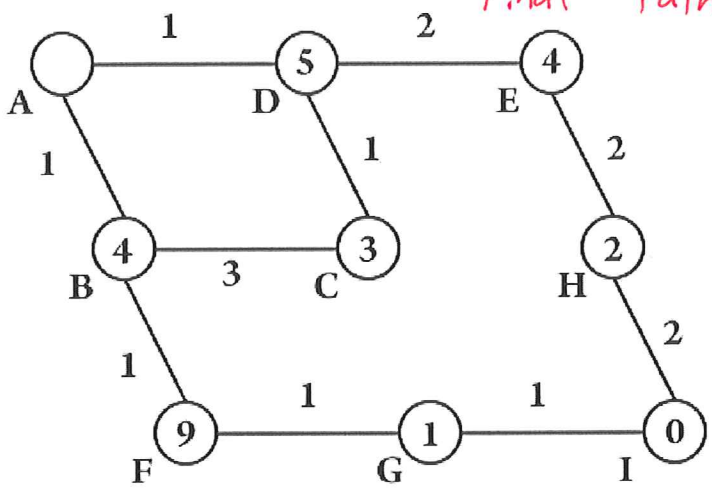
b. (*8 pts*) Now imagine that you can rotate or flip the obstacle while not moving it or the goal. How would you change the environment to make the bug algorithm that you didnt choose above produce the shorter path?

flip the spiral ~~vertical~~ about the horizontal

(change bug to turn left also works)

2. *(20 points)*

a. *(8 pts)* For the graph below, run the A-Star algorithm and report the nodes visited in order, and the best path that A-Star returns. Start at node A and the goal is node I. The heuristic values are the numbers inside the nodes, and the numbers on the edges are their cost.



Final Path ✓ A→D→E→H→I

back pointer
B→A
D→A
~~C→B~~ C→D
F→B
E→D
H→E
I→H

open
~~B 5~~
~~D 6~~
~~C 7 6 8~~
F 11
~~E 7~~
~~H 7~~
~~I 7~~

closed
A
B
D
C
E
H
I

b. *(8 pts)* Did A-Star return the correct shortest path? Why or why not? If it did not, what number would you change to garentee that the path A-Star returns is the shortest?

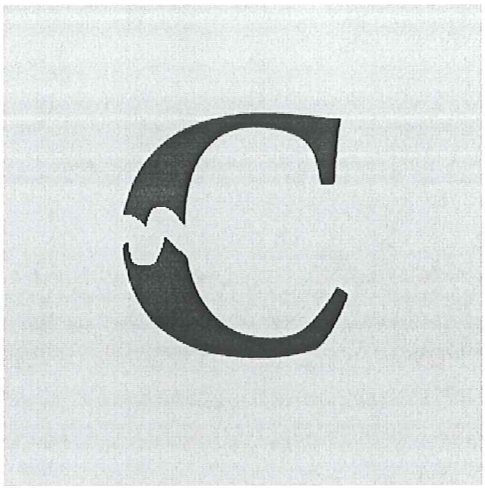
No, Astar did not return the shortest path. This is because the heuristic at node F is an overestimate of the true distance, so a star didn't close the node. The true distance of F is 2, but any number 4 or less would yield the correct path.

c. *(4 pts)* What type of graph search is A-Star? Why?

Informed, as it uses heuristic information and path cost to search for good pathes.

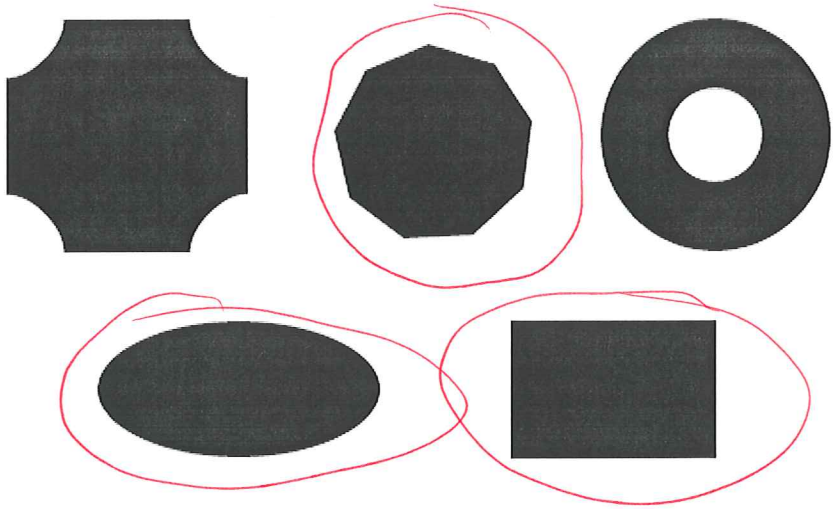
3. (*9 points*)

a. (*3 pts*) After running the blob-fill algorithm, assigning 0 for the background and increments of 1 for blobs, how many different values will the result have?



3

b. (*3 pts*) How many of the following shapes are convex? Circle them.



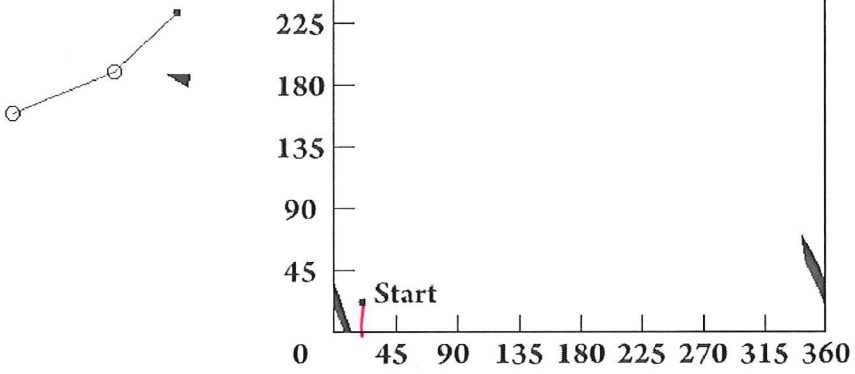
3

c. (*3 pts*) What is the L1 distance between (0,0) and (2,1)?

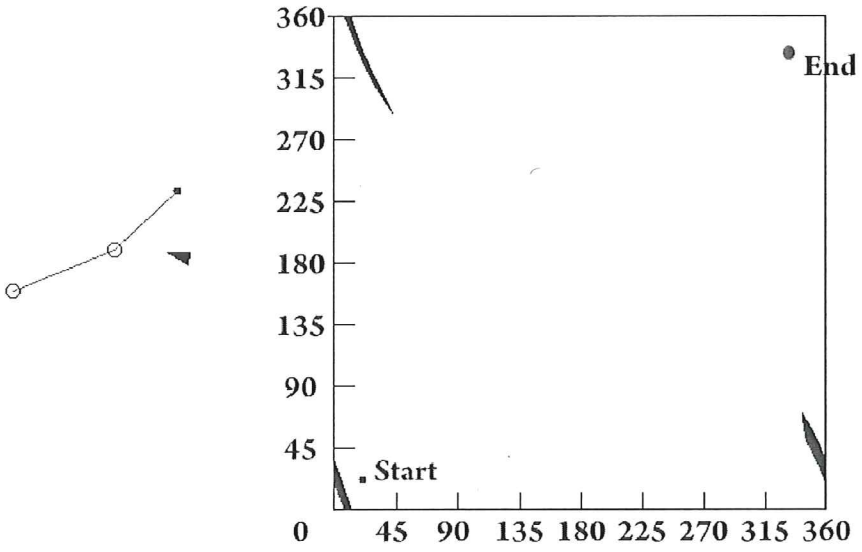
3

4. (*16 points*) This problem uses a two link arm which is broken, and can only move within $\pm 45°$ of its zero configuration for the first two parts. The starting configurations and associated configuration spaces are shown.

a. (*4 pts*) Draw the shortest path in configuration space, or report NO PATH if none exists.

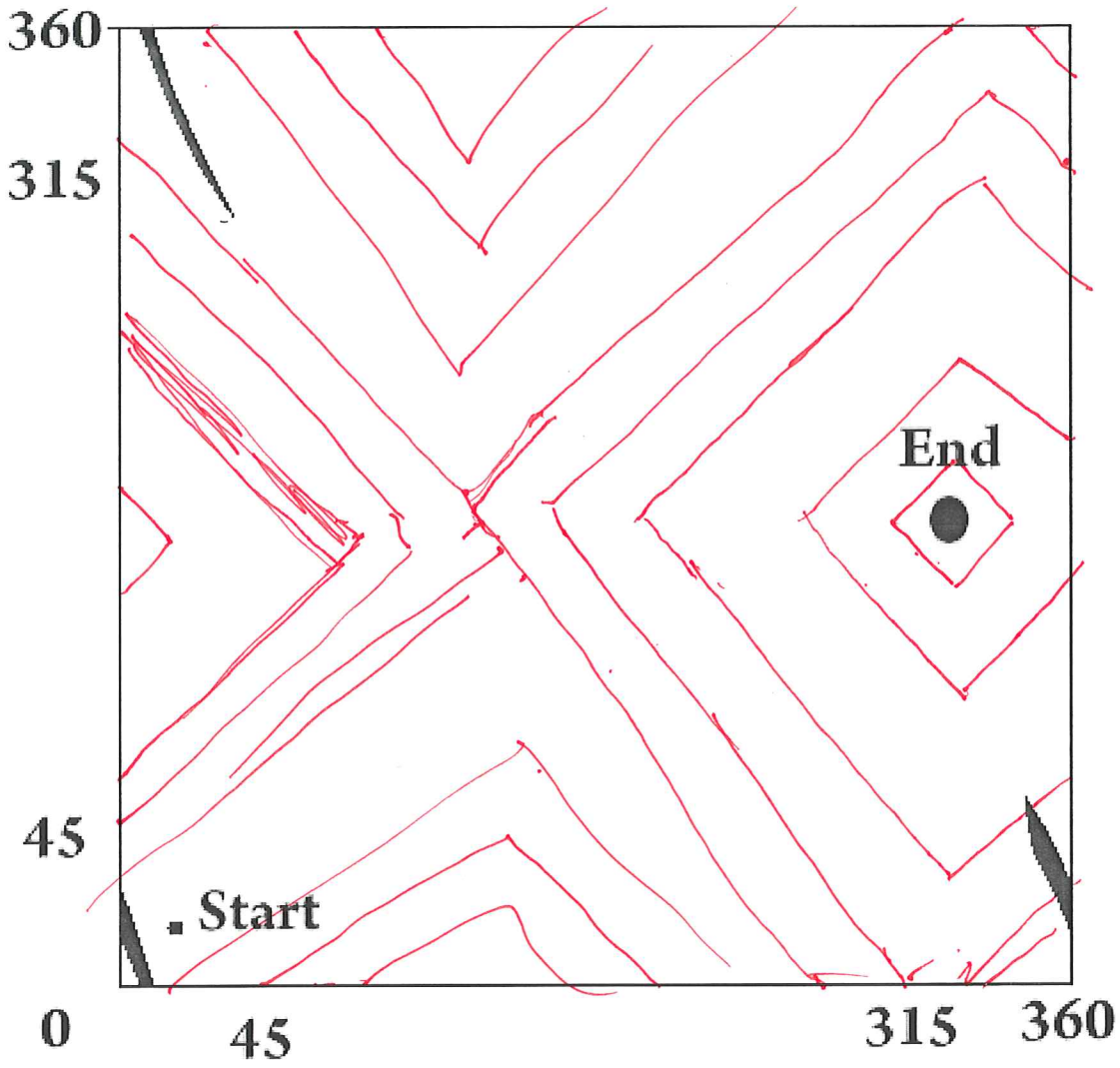


b. (*4 pts*) Draw the shortest path in configuration space, or report NO PATH if none exists.



NO PATH

c. (*4 pts*) The arm has been fixed! Now draw the L1 wavefronts that would results in this new goal position. Draw at least 8 waves to show that you understand the shapes.



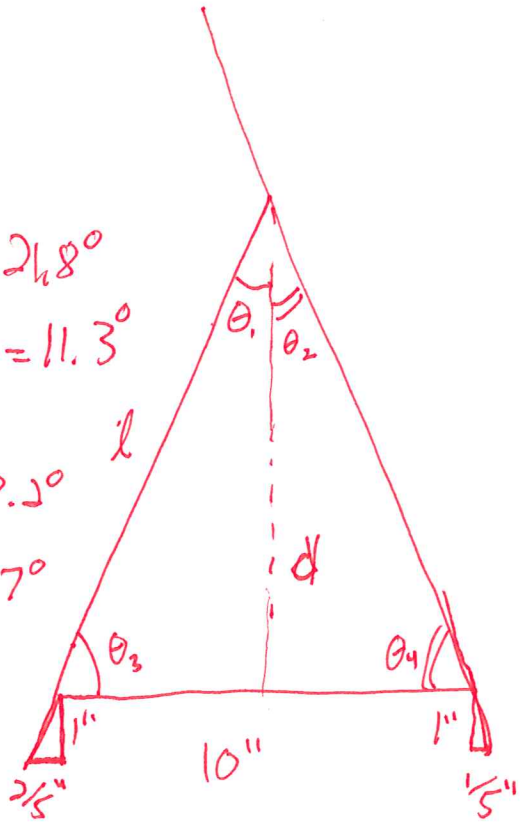
5. (*15 points*) A robot is examining your head TA using its stereo pair of cameras. The cameras are 10 inches apart, with a focal length of 1 inch. You head TA appears 10 pixels to the left of the right camera's centerline, and 20 pixels to the right of the left camera's centerline. Assume the picture has a resolution of 50 pixels per inch. Draw a picture, and solve for how far away the head TA is from your robot (depth only please).

$\theta_1 = \text{atan}\left(\frac{2/5}{1}\right) = 21.8°$

$\theta_2 = \text{atan}\left(\frac{1/5}{1}\right) = 11.3°$

$\theta_3 = 90 - \theta_1 = 68.2°$

$\theta_4 = 90 - \theta_3 = 78.7°$



Law of Sines

$$\frac{10''}{\sin(\theta_1+\theta_2)} = \frac{l}{\sin\theta_4} \qquad l = \frac{10 \cdot \sin 78.7}{\sin(33.1)} = 17.96''$$

$$d = l \sin\theta_3 = 17.96 \cdot \sin(68.2) = \boxed{16.67''}$$

6. (*20 points*) Given the masks:

$$A = \begin{pmatrix} \frac{1}{9} & \frac{1}{9} & \frac{1}{9} \\ \frac{1}{9} & \frac{1}{9} & \frac{1}{9} \\ \frac{1}{9} & \frac{1}{9} & \frac{1}{9} \end{pmatrix} \quad B = \begin{pmatrix} 1 & 0 & -1 \\ 1 & 0 & -1 \\ 1 & 0 & -1 \end{pmatrix}$$

a. (*5 pts*) What do the two masks do? Please justify your answers.

A averages the numbers in each 3x3 neighborhood, performing a blur. B takes the horizontal numberical first difference, which will detect vertical edges.

b. (*8 pts*) If you applied mask A to an image several hundred times, and then applied mask B to the result, what would expect the output values to be? Please justify your answer.

All 0's, because the blurs would average the image to all be the same number, and the first difference would be 0.

c. (*7 pts*) Design a 3x3 mask that to detect edges that are at a 45 degree angle to the horizontal.

$\begin{bmatrix} 0 & 1 & 0 \\ 1 & 0 & -1 \\ 0 & -1 & 0 \end{bmatrix}$ or $\begin{bmatrix} 1 & 1 & 0 \\ 1 & 0 & -1 \\ 0 & -1 & -1 \end{bmatrix}$ or transposes